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Request for grant of a patent

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1.	Your reference	PDG/20637
2.	Patent application number *(The Patent Office will fill in this part)* 9810555.4	15 MAY 1998
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	SNELL & WILCOX LIMITED 6 Old Lodge Place St Margaret's Twickenham Middlesex TW1 1RQ
	Patents ADP number *(if you know it)*	5579784003
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	VIDEO SIGNAL PROCESSING
5.	Name of your agent *(if you have one)*	MATHYS & SQUIRE
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	100 Gray's Inn Road London WC1X 8AL UNITED KINGDOM
	Patents ADP number *(if you know it)*	1081001

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Continuation sheets of this form	
Description	4
Claim(s)	1
Abstract	-
Drawing(s)	1 +1

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	- 1
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature ________ Date 15 May 1998

MATHYS & SQUIRE

12. Name and daytime telephone number of person to contact in the United Kingdom

Peter D Garratt - 0171 830 0000

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Notes

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VIDEO SIGNAL PROCESSING

This invention relates to video signal processing and is particularly concerned with non-linear filtering.

It has been found that in a wide variety of video signal processes - including de-interlacing, decoding, enhancement, noise reduction, and standards conversion - considerable advantage can be secured by the use of complex non-linear filters. It has been found in particular that polynomial filters can be very useful. In many applications, quadratic behaviour in the filter is not sufficient and third or higher orders are typically necessary. Where real time operation is required, hardware implementations are usually essential and the hardware costs of such high order polynomial filters are substantial.

It is an object of the present invention to provide improved methods and apparatus in video signal processing which offer third or higher order behaviour in a relatively simple filter architecture.

Accordingly, the present invention consists, in one aspect, in a method of video signal processing in which the outputs of at least three linear filters are multiplied together.

Preferably, the product of the outputs of two filters is formed and a linear filtering operation conducted on that product, prior to multiplication by the output of the third filter output.

In one form of the invention, linear and non-linear filtering operations are conducted in parallel with the results of said operations being combined to produce an output; the non-linear filter operation comprising the multiplication together of the outputs of at least three linear filters.

In another aspect, the present invention consists in apparatus for video signal processing comprising an input terminal for receiving an input video signal; first, second and third linear filters each connected with the input terminal; a first multiplier for multiplying together the respective outputs of the first and second filters; and a second multiplier for multiplying together the respective outputs of the first multiplier and the third filter.

Advantageously, a filter is interposed between the output of the first multiplier and the second multiplier.

Preferably, the apparatus further comprises a linear filter path connected with the input terminal, and a combiner for combining the outputs of the linear filter path with the output of said second multiplier.

Suitably, a filter is interposed between the output of the second multiplier and said combiner.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a block diagram of video signal processing apparatus according to the invention, in the form of a vertical de-interlacing filter;

and

Figure 2 is a diagram similar to Figure 1, illustrating a modification.

The embodiment of a vertical de-interlacer is used to exemplify the present invention for reasons of simplicity. Better results can be obtained by also using horizontal and/or temporal information in ways which will be evident. The filter could equally well be applied to the other problems in video processing.

In Figure 1, the new architecture can be seen to consist of two signal paths. The linear signal path contains a traditional, vertical, six tap, linear filter (h_{lin}) which has a typical sin(x)/x structure. If this were to be used without the non-linear signal path it would produce reasonable pictures, but they would contain some artefacts due to the interpolation process, notably jagging on diagonal and curved edges.

In the non-linear signal path, the output of two four point linear filters (h_1 and h_2) are multiplied together and passed through a two point linear filter (h_4). The output of this is then multiplied with the output of a five point

linear filter (h_5). Finally the resulting signal is filtered through another two point linear filter (h_6) before being added on to the linear path. Although in this case the filter lengths are 4, 5 and 2, larger filters with more taps can be used to give better results. The lengths (or more generally, the sizes) of the filters need not be related and can be made larger or smaller to provide different trade-offs between quality and cost.

The filter coefficients are selected by 'training' the filter on real pictures. In this example of de-interlacing a still frame is taken and split into fields. A set of coefficients is used to estimate Field 2 from Field 1 and the mean squared error between the estimate of Field 2 and the original Field 2 is measured. A genetic algorithm can then be used to search the multi-dimensional filter space for the set of filter coefficients that gives the lowest mean squared error.

If this non-linear de-interlacer is tried on the EBU/SMPTE test picture "Girl with Toys", the non-linear path is found to reduce the average mean squared error by approximately 15% with respect to the linear filter. There is also a noticeable reduction in jagging. A polynomial filter with the same number of input pixel taps produces an almost equivalent reduction in error.

A major advantage of this new architecture over the polynomial filter can be seen by considering the number of multiplications of pixels; multiplications of pixels by a constant; and additions, that each filter requires. These are shown in Table 1.

	Polynomial Filter	New Architecture
Multiplication	50	2
Multiplication by a constant	34	23
Additions	34	24

Table 1 : Comparison of complexity of filters

It can be seen that the largest reduction is in the multiplication of pixels. This is particularly significant as these are the most expensive to implement.

In summary, the new architecture is able to reduce many of the artefacts associated with traditional linear interpolation whilst being relatively simple to implement.

Figure 2 illustrates a modification in which the architecture is simplified through omission of the filters h_4 and h_6. In other words, the direct product is formed of the outputs of filters h_1, h_2 and h_3 without intervening filtering of the product of the outputs of filters h_1 and h_2. This may under some circumstances produce less ideal filter behaviour, but the reduction in hardware complexity will often more than compensate. A particular advantage is that the three remaining filters can all make use of the same memory architecture.

It should be understood that this invention has been described by way of example only and that a wide variety of modifications are possible without departing from the scope of the invention. Thus, whilst the separation into linear and non-linear paths offers important advantages, such as the option to preserve higher bit accuracy in the linear path, it will not always appropriate. Similarly, the described use of vertical filters is - as has been explained - merely an example. Horizontal, vertical and temporal filters can be employed and filters can have one, two or three of these dimensions. Whilst, FIR filters will be important, the invention also encompasses other forms of linear filter such as recursive filters. The filters which are to be multiplied together need not be of the same category.

CLAIMS

1. A method of video signal processing in which the outputs of at least three linear filters are multiplied together.

2. A method according to Claim 1, wherein the product of the outputs of two filters is formed and a linear filtering operation conducted on that product, prior to multiplication by the output of the third filter output.

3. A method according to Claim 1 or Claim 2, wherein linear and non-linear filtering operations are conducted in parallel, with the results of said operations being combined to produce an output; the non-linear filter operation comprising the multiplication together of the outputs of at least three linear filters.

4. Apparatus for video signal processing comprising an input terminal for receiving an input video signal; first, second and third linear filters each connected with the input terminal; a first multiplier for multiplying together the respective outputs of the first and second filters; and a second multiplier for multiplying together the respective outputs of the first multiplier and the third filter.

5. Apparatus according to Claim 4, wherein a filter is interposed between the output of the first multiplier and the second multiplier.

6. Apparatus according to Claim 4 or Claim 5, wherein the apparatus further comprises a linear filter path connected with the input terminal, and a combiner for combining the outputs of the linear filter path with the output of said second multiplier.

7. Apparatus according to Claim 6, wherein a filter is interposed between the output of the second multiplier and said combiner.

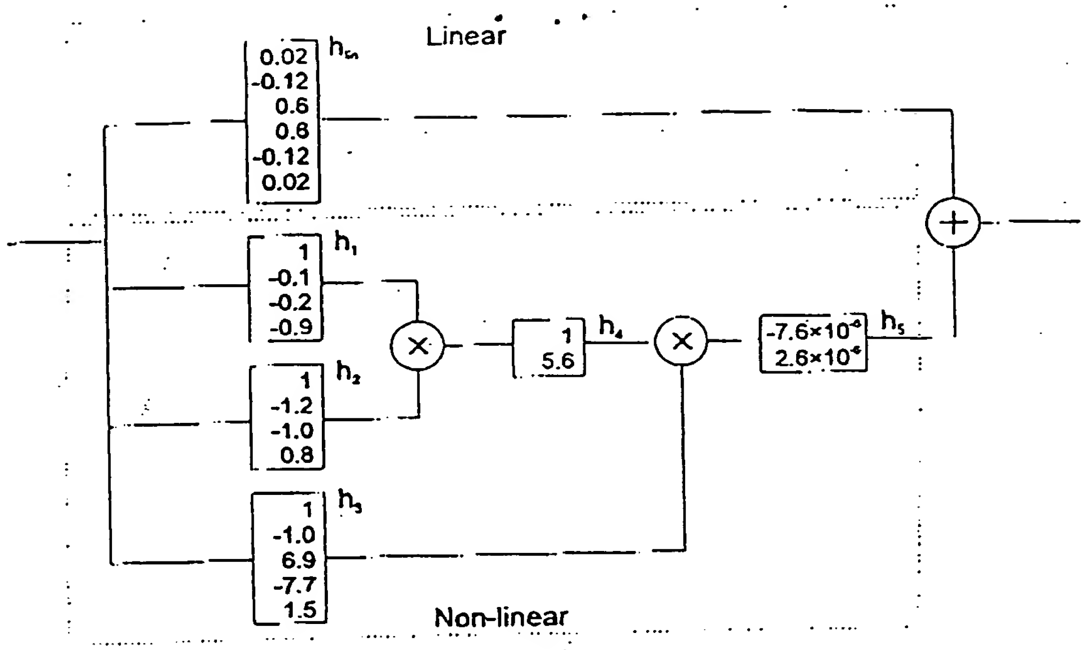

Figure 1

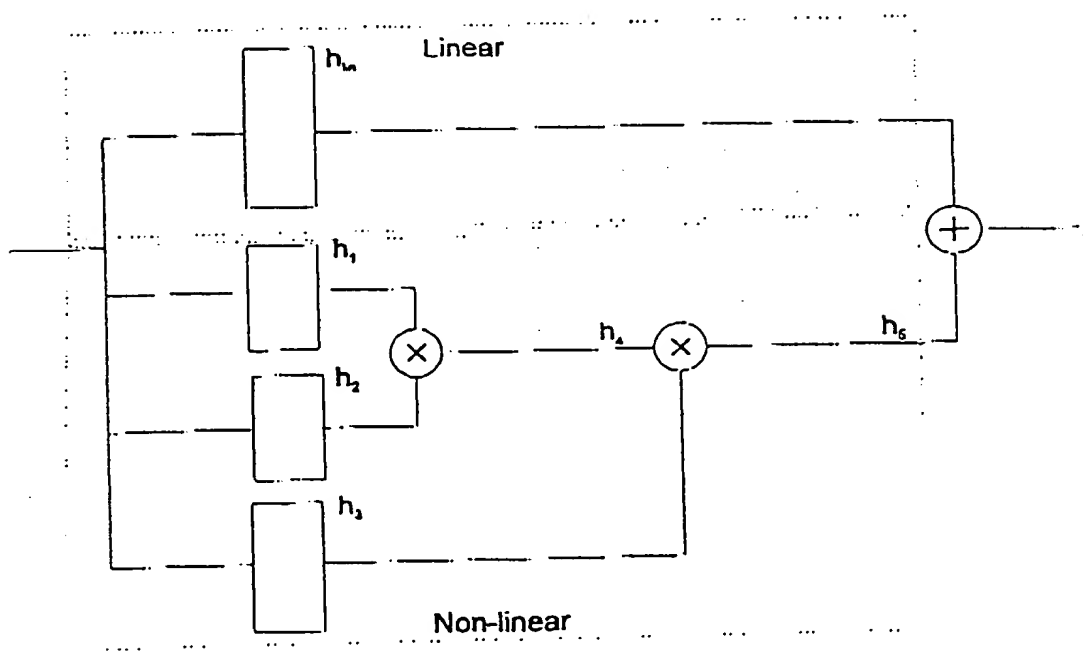

Figure 2